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Utilization of aphid leaf-roll galls on lammas shoots of *Prunus* × *yedoensis* Matsumura (Rosaceae) by a myrmecophilous butterfly *Niphanda fusca* (Bremer et Grey) (Lepidoptera, Lycaenidae) for oviposition sites

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Abstract A female of a myrmecophilous butterfly, *Niphanda fusca* (Lepidoptera, Lycaenidae), was observed in July 2004 to lay eggs on leaf-roll galls induced by *Myzus siegesbeckiae* (Hemiptera, Aphididae) on lammas shoots of a cherry tree in Fukuoka Prefecture, Japan. Presence of the host ant, *Camponotus japonicus* (Hymenoptera, Formicidae), was not necessary for the *N. fusca* female to lay eggs. Many lammas shoots were produced from one of the cherry trees surveyed, due to heavy trimming in June 2004, and every lammas shoot was galled by *M. siegesbeckiae* colonies. The *N. fusca* female did not lay eggs on cherry trees with fewer lammas shoots. On the basis of previous and our current observations, we note that *N. fusca* is one of the late season emergent butterflies that inevitably use lammas shoots as oviposition targets instead of spring shoots. Lammas shoots are unpredictable targets in time, space, and quantity, because they are produced as a compensatory reaction to natural or artificial defoliation. We therefore discuss the importance of management practices in promoting lammas shoot production that may help to prevent the decline of *N. fusca* populations that has occurred in recent years. We also emphasize the necessity to study interactions between insects that affect the abundance of *N. fusca*.

Key words *Niphanda fusca*, aphid leaf-roll gall, lammas shoot, oviposition site, management practice.

Introduction

Niphanda fusca (Bremer et Grey) (Lepidoptera, Lycaenidae) is distributed in Japan (except Hokkaido), NE and E China, the Korean Peninsula (*e. g.* Hirukawa, 1985), and SW Transbaikalia (the steppe areas in the Selenga River basin), SE and E Transbaikalia, Amurland, Primorye, Russia (Gorbunov & Kosterin, 2003). This butterfly has been known as one of the myrmecophilous species, being associated with *Camponotus japonicus* Mayr (Hymenoptera, Formicidae) in Japan (*e. g.* Hirukawa, 1985). Since Nagayama (1950) clarified the myrmecophilous life history of *N. fusca*, a wide variety of observations on this butterfly and its associated ant have been reported in the Japanese language and Hirukawa (1985) referred to 165 such reports in his book (see references in the book for further information). Eggs and larvae of *N. fusca* have been found near aphid colonies on newly extending shoots of various plants, such as *Quercus* trees (Fagaceae), saplings of *Pinus* and *Larix* species (Pinaceae), and grasses, including *Miscanthus sinensis* Andersson (Poaceae) (*e. g.* Hirukawa, 1985; Nakamura, 2006). These plants are growing in semi-natural environments such as coppiced woodlands, grasslands, and agricultural lands that have been maintained by traditional practices. *Niphanda fusca* has also been observed to lay eggs near colonies of *Psylla eleaguni* Kuwayama (Hemiptera, Psyllidae) (Fukuda, 1957; Fukuda, & Tanaka, 1973).

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In recent years, *N. fusca* has been gradually declining mainly due to road construction, deforestation, and residential development (Sibatani, 1990), becoming extinct in 18 out of 44 prefectures in Japan, and designated as one of the endangered insect species in Japan (Category I) (Nakamura, 2006).

In July 2004, we observed two adults of *N. fusca* flying around two artificially planted cherry trees, *Prunus* × *yedoensis* Matsumura (Rosaceae), in a gap between plantations of *Cryptomeria japonica* (Linnaeus) D. Don (Taxodiaceae) in Sasaguri Town, Fukuoka Prefecture, Japan (longitude, latitude, and altitude of the location are not indicated to avoid further collection of the butterfly by thoughtless collectors). One of the *N. fusca* adults laid eggs on leaf-roll galls induced by an aphid species on lammas shoots of one of the two cherry trees. In the temperate zone, trees normally produce spring shoots once a year, but the production of shoots in other seasons than spring can be seen frequently in various tree species (Simbolon & Yukawa, 1993*b*). These shoots are called lammas shoots, which are generally produced as a compensatory reaction to defoliation by herbivores and to other factors, such as mechanical injury caused by strong winds and human operations (Okuda & Yukawa, 2000).

We would not have expected the occurrence of *N. fusca* in a gap between *Cryptomeria* plantations, where no trees representative of coppiced woodlands were growing. Oviposition by *N. fusca* on aphid leaf-roll galls induced on cherry trees has never been reported, although Takahashi *et al.* (1973) observed that eggs were laid near bud galls induced on *Hamamelis japonica* Siebold & Zuccarini (Hamamelidaceae) by *Hamamelistes betulinus miyabei* (Matsumura) (Hemiptera, Pemphigidae) (as *Mansakia* sp. in Takahashi *et al.*, 1973, but see pp. 57 and 215 in Yukawa & Masuda, 1996 for the name of the gall-inducing pemphigid).

In this paper, we report our observations on the oviposition habit of *N. fusca* and discuss interrelations between lammas shoot production of forest trees and late season emergent butterflies such as *N. fusca*. Simbolon & Yukawa (1993*a*, *b*) and Okuda & Yukawa (2000) have demonstrated a similar example for *Lithocarpus edulis* (Makino) Nakai (Fagaceae) and the associated insects, including a late season emergent gall midge, *Tokiwadiplosis matecola* Okuda & Yukawa (Diptera, Cecidomyiidae).

Field survey

On 11 July 2004 (at 1:00 pm), we observed, for about five minutes, two *N. fusca* adults flying around the two cherry trees and laying eggs on aphid-leaf roll galls induced on lammas shoots of one of the two cherry trees. After that, we examined aphid-leaf roll galls on the trees to find eggs of the butterfly. Then, in order to evaluate abundance of lammas shoots and aphid galls, we recorded the number of rolled and unrolled leaves on lammas shoots for the two cherry trees (Fig. 1; Tree 1, about 1.2 m in height and Tree 2, about 2.0 m in height). At the same time, we surveyed insects that were associated with the lammas shoots. Gall-inducing aphids and attending ants were identified by Prof. M. Sorin (Kôgakkan University) and Prof. K. Ogata (Kyushu University), respectively. On the same day, we randomly surveyed lammas shoots of various forest trees growing in a secondary forest that is about 1 km distant from the *Cryptomeria* plantations.

On 6 July 2005, we surveyed again the abundance of lammas shoots and searched for *N. fusca* eggs on the same cherry trees (Trees 1 and 2) that we had surveyed in 2004. These cherry trees were not trimmed in 2005. We surveyed 13 additional cherry trees (3.1–4.3 m in height, 5.9–14.0 cm in DBH) growing in the same gap between the *Cryptomeria* plantations and the numbers of fresh rolled and unrolled leaves attached to randomly selected

Fig. 1. Two cherry trees surveyed. The front tree (Tree 1) has many lammas shoots and the hind tree (Tree 2) is taller but with a relatively few lammas shoots.

lammas shoots were recorded. We also surveyed lammas shoots of various forest trees growing in the same secondary forest that we had visited in 2004.

Results

On 11 July 2004, we observed the two *N. fusca* adults flying erratically around the cherry trees. One of them laid eggs one by one on lammas shoots within a few minutes. It took a few seconds to lay one egg. The female flew away soon after laying three eggs. Another *N. fusca* adult flew over the cherry trees for a few seconds and quitted soon without laying eggs.

According to a gardener, the two cherry trees were heavily trimmed in June 2004 to remove leaves infested by unidentified insect herbivores, and many lammas shoots were produced

Table 1. Number of rolled and unrolled leaves attached to respective lammas shoots of cherry tree (Tree 1) and insects associated with the shoots.

Shoot No.	Leaves attached	Rolled leaves	Unrolled leaves	Associated insects other than aphids
1	6	6	0	
2	8	8	0	
3	7	7	0	
4	8	8	0	A syrphid larva
5	5	5	0	
6	7	7	0	A syrphid egg
7	7	7	0	Ants
8	11	11	0	
9	5	5	0	
10	4	4	0	Two syrphid eggs; ants
11	10	10	0	
12	13	13	0	Ants
13	17	17	0	
14	18	18	0	A syrphid larva
15	16	16	0	A lepidopteran larva
16	23	23	0	A syrphid egg & a larva
17	10	10	0	
18	23	23	0	A syrphid egg & a larva
19	19	19	0	An *N. fusca* egg
20	18	18	0	Lepidopteran larvae & thrips
21	22	22	0	A syrphid egg
22	11	11	0	Two *N. fusca* eggs

thereafter (Fig. 1). On Tree 1, all (100%) new leaves attached to 22 lammas shoots examined were rolled by *Myzus siegesbeckiae* Takahashi (Hemiptera, Aphididae) and three *N. fusca* eggs were found on two of these lammas shoots (Table 1). On Tree 2, only five among 20 shoots examined bore leaves rolled by aphids and the proportion of rolled leaves to unrolled leaves was very low (Table 2). We could not find *N. fusca* eggs on this tree, although an *N. fusca* female was observed flying around it.

We collected two ant species, *Pristomyrmex pungens* Mayr and *Paratrechina flavipes* (F. Smith) (Hymenoptera, Formicidae), from the two cherry trees. *Camponotus japonicus*, which is a known host of *N. fusca*, was not found on these trees but was observed on the ground. We found some other insects on the trees, such as lepidopteran larvae and syrphid eggs and larvae, but they were not identified to the species level as they were in early stages of development (Tables 1 and 2). On Tree 1, syrphid eggs or larvae were found on seven (31.8%) out of the 22 lammas shoots examined and two (9.1%) of the 22 lammas shoots were infested by lepidopteran larvae (Table 1). On Tree 2, only one syrphid larva was found on a rolled leaf, while ten of 20 shoots were infested by lepidopteran larvae (Table 2). Curiously, a coccinellid larva was found on a lammas shoot without rolled leaves.

In the secondary forest, we found a total of 11 lammas shoots on *Quercus glauca* Thunberg (Fagaceae) and *Clerodendron trichotomum* Thunberg (Verbenaceae), but no aphid colonies were detected on both plants.

In 2005, no lammas shoots were produced, hence no rolled leaves were found on Trees 1 and 2. Among 13 additional cherry trees surveyed, four trees bore leaves rolled by *M. siegesbeckiae* and the proportion of rolled leaves among whole fresh leaves examined was only 4.11 % (25/608) (Table 3). No *N. fusca* eggs and attending ants were found on these

Table 2. Number of rolled and unrolled leaves attached to respective lammas shoots of cherry tree (Tree 2) and insects associated with the shoots.

Shoot No.	Leaves attached	Rolled leaves (leaf position*)	Unrolled leaves	Associated insects other than aphids (leaf position*)
1	10	2 (1, 8)	8	Two lepidopteran larvae (5)
2	4	0	4	A lepidopteran larva (4)
3	6	0	6	
4	4	0	4	
5	6	0	6	A lepidopteran larva (1)
6	7	0	7	
7	6	3 (1, 2, 3)	3	
8	9	0	9	Two lepidopteran larvae (6)
9	10	0	10	
10	9	0	9	
11	8	2 (2, 5)	6	A lepidopteran larva (4, 7); A syrphid larva (2)
12	7	0	7	
13	4	0	4	A coccinellid larva (3)
14	8	0	8	A lepidopteran larva (3)
15	9	0	9	
16	2	0	2	Two lepidopteran larva (1, 2)
17	17	2 (1, 2)	15	Two lepidopteran larva (6, 10)
18	5	0	5	Two lepidopteran larva (1, 2)
19	9	0	9	Two lepidopteran larva (2, 3)
20	21	6 (4, 10–14)	15	

*Leaf position from the top of shoot

rolled leaves, although one *N. fusca* adult was observed flying around these cherry trees at 2: 00 pm on 6 July 2005. Again, we found several lammas shoots on *Q. glauca* and *C. trichotomum* in the secondary forest, but aphid colonies, attending ants, and *N. fusca* eggs were not detected on both plants.

Discussion

According to previous observations (*e. g.* Hirukawa, 1985), presence of the host ant, *C. japonicus*, on aphid colonies was usually necessary for *N. fusca* to lay eggs, but our observations indicated that the presence of host ants was not always necessary for egg laying and *N. fusca* females did not seem to spend enough time for recognition of ant attendance before oviposition. Because we observed *C. japonicus* workers crawling on the ground, they may have chance to find *N. fusca* larvae on the cherry tree.

Artificial leaf cutting experiments indicated that *Lithocarpus edulis* (Fagaceae), *Quercus glauca* (Fagaceae), and *Camellia japonica* (Theaceae) produced lammas shoots more frequently than species of Lauraceae (Simbolon & Yukawa, 1993*b*). As mentioned in the introduction, lammas shoots are generally produced as a compensatory reaction to defoliation by herbivores and to other factors. The appearance of lammas shoots is, therefore, relatively unpredictable in time, space, and quantity, for insect herbivores to utilize them as food resources (Okuda & Yukawa, 2000). Despite such unsuitableness, a monophagous gall midge, *Tokiwadiplosis matecola* Simbolon et Yukawa (Diptera, Cecidomyiidae), utilizes only lammas shoots for galling instead of normal spring shoots of *L. edulis* (Simbolon & Yukawa, 1992, 1993*a*, *b*), because *T. matecola* requires relatively high temperatures for larval development after overwintering and the emergence of *T. matecola*, therefore, cannot synchronize with the appearance of spring shoots (Okuda & Yukawa, 2000).

Table 3. Number of rolled and unrolled fresh leaves attached to lammas shoots of cherry trees.

Tree No.	Fresh leaves examined	Fresh leaves rolled	Fresh leaves unrolled
3	68	8	60
4	10	2	8
5	33	2	31
6	61	0	61
7	46	13	33
8	34	0	34
9	43	0	43
10	33	0	33
11	36	0	36
12	53	0	53
13	71	0	71
14	80	0	80
15	40	0	40
Total	608	25	583

Niphanda fusca seems to be one of the late season emergent insects like *T. matecola*, but is fundamentally different from *T. matecola* in geographical distribution range. *Tokiwadiplosis matecola* inhabits broad-leaved evergreen forests in warm southern parts of Kyushu, Japan and overwintered larvae required temperatures higher than 15°C to develop to the pupal stage (Okuda & Yukawa, 2000), while *N. fusca* is distributed in Siberia (Gorbunov & Kosterin, 2003) and must have a relatively low developmental zero point to live there. Nevertheless, *N. fusca* adults start to appear in June (*e. g.* Hirukawa, 1985) even in the warm temperate zone like Japan, although the reason is still unclear. Therefore, they cannot synchronize with the timing of spring shoot production and cannot use abundant spring shoots, which are more predictable than lammas shoots in time and space for aphid colonization and *N. fusca* oviposition.

Niphanda fusca, thus, inevitably searches lammas shoots for oviposition sites because aphids always colonize fresh shoots, and aphid galls can be outstanding targets for oviposition. Our data indicated that trees with more numerous lammas shoots seemed to be more attractive to *N. fusca* females than those with few lammas shoots. From this point of view, we are able to agree with previous observations that *N. fusca* was frequently present in secondary forests dominated by *Quercus* trees (*e. g.* Hirukawa, 1985), because *Quercus* species more readily produce lammas shoots than other trees as a compensatory reaction to defoliation (Simbolon & Yukawa, 1993*b*). In addition to large scale factors such as road construction, deforestation, and residential development (Sibatani, 1990), gradual decline of *N. fusca* in secondary forests may be related to reduction of lammas shoot production due to the abandonment of traditional management practices that have been artificially promoting lammas shoot production. Grassland has been known to be another appropriate habitat for *N. fusca*, because new shoots that are favored by aphids are continuously produced from various plant species. Even in grassland, management practices such as mowing and burning the dead grass are needed to promote further production of new shoots.

Other biological factors also influence lammas shoot production directly and indirectly and affect survival of *N. fusca*. Heavy infestation of spring shoots by defoliators would promote lammas shoot production (Simbolon & Yukawa, 1993*a*, *b*), while other defoliators on lammas shoots, such as lepidopteran larvae observed in this study, would reduce fresh leaves utilized by aphid colonies. Syrphids and coccinellids feed on aphids and so reduce oviposition targets of *N. fusca*. In order to monitor the abundance of *N. fusca*, direct and indirect

interactions between associated insects should be intensively studied at the population and community levels.

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摘　　要

サクラのラマスシュートに形成されたアブラムシのゴールを産卵対象とするクロシジミ (チョウ目, シジミチョウ科) (我那覇智子・岡本智恵・湯川淳一)

2004年7月に, 福岡県で, サクラのラマスシュート (遅れ芽, 土用芽) に, ヒキオコシコブアブラムシ *Myzus siegesbeckiae* (半翅目, アブラムシ科) によって形成された葉巻状のゴール上に, クロシジミ *Niphanda fusca* (鱗翅目, シジミチョウ科) が産卵するのが観察された. このとき, クロオオアリ (膜翅目, アリ科) の随伴は認められず, クロシジミの産卵には, クロオオアリの存在が, 必ずしも, 必要ではなかった. しかし, 地面にはクロオオアリのワーカーが徘徊していたので, いずれ, 樹上のクロシジミ幼虫に遭遇する機会もあろう. 調査木のうち, 一本のサクラには, 2004年の6月の強剪定によって多数のラマスシュートが形成されており, どのシュートにも, ヒキオコシコブアブラムシのコロニーがゴールを形成していた. クロシジミは, ラマスシュートの多い木に産卵したが, 少ない木に産卵することはなかった. ラマスシュートは, 自然的, あるいは人為的要因によって生じた落葉に対する補償作用で生

じるため, その形成は時間的にも空間的にも量的にも予測が困難である. これまでの報告と, 今回の我々の観察から, クロシジミは, 安定的に供給される春のシュートを利用できず, ラマスシュートを産卵対象とせざるを得ない季節遅れのチョウであることを指摘した. 本稿では, 近年のクロシジミ個体群の衰退を防ぐ観点から, ラマスシュートの形成を促す環境管理の重要性に言及するとともに, クロシジミをめぐる生物環境要因の相互作用に関する研究の必要性を強調した.

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